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The Pitch Pine Tip Moth and Its Occurrence in Ohio

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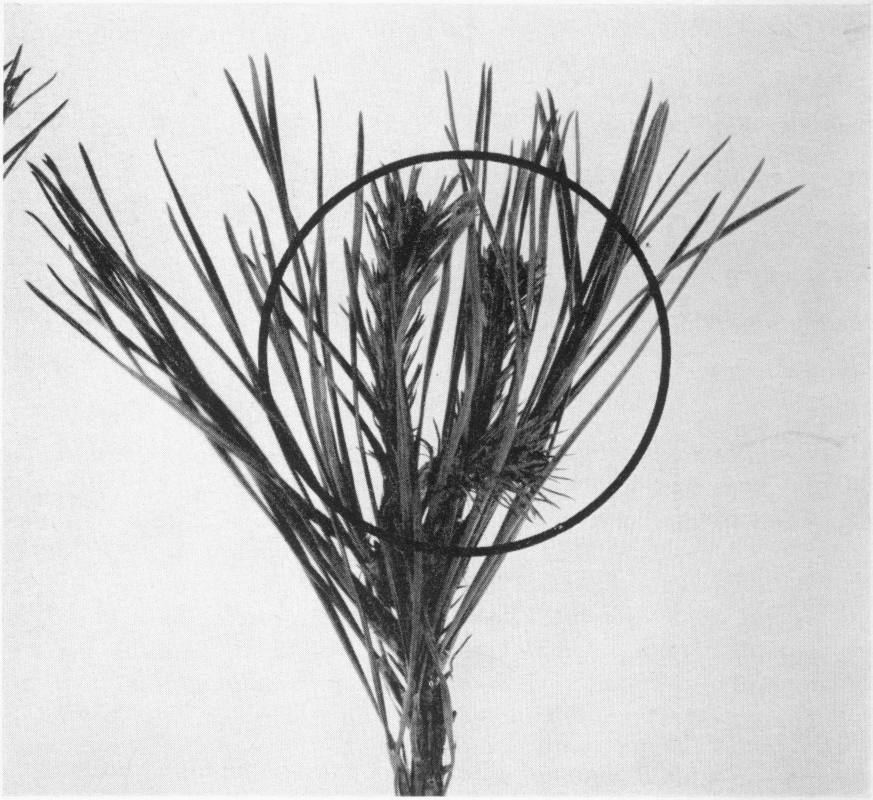

OHIO AGRICULTURAL EXPERIMENT STATION - - - WOOSTER, OHIO

CONTENTS

* * *

Introduction ---------- 3

Taxonomy ---------- 4

Geographic Distribution ---------- 6

Rhyacionia Rigidana Versus Rhyacionia Frustrana in Ohio ---------- 10

Hosts ---------- 11

Seasonal History ---------- 13

Parasites and Predators ---------- 18

Incidence ---------- 19

Injury ---------- 20

Summary and Conclusions ---------- 21

Literature Cited ---------- 22

Acknowledgments ---------- 23

The Cover—

A tip of shortleaf pine killed by the pitch pine tip moth.

THE PITCH PINE TIP MOTH, *RHYACIONIA RIGIDANA* (FERNALD), AND ITS OCCURRENCE IN OHIO (LEPIDOPTERA, OLETHREUTIDAE)

WILLIAM E. MILLER[1] and RALPH B. NEISWANDER[2]

INTRODUCTION

Rhyacionia rigidana (Fernald) is discussed in most reference works on American forest insects, but it is not a well known species. Its larvae develop in pine tips, and in many ways the insect is similar to the better known Nantucket pine moth, *R. frustrana* (Comstock). Adults of these two species can be differentiated, but no way to reliably distinguish immature individuals has yet been found. Heinrich in 1923 wrote concerning *R. rigidana*:

> "I have several times in recent years reared the moth from larvae feeding in the buds of various pines also infested with the larvae of the Nantucket pine moth____. The two species____ are probably confused in the economic references to *frustrana*. Fernald's species *(R. rigidana)*, however, seems to be more local. While its distribution in the East probably corresponds roughly to that of *frustrana*, it is to be found only in localities here and there____."

In the more than three decades since the above observations were written, ecological knowledge of *R. rigidana* has progressed very little. Facts with which to properly evaluate the insect's economic importance also have been slow to accumulate.

The present paper gives new information on *Rhyacionia rigidana* and it assembles past information about the species. Field studies were made from 1951 through 1953 in Ohio. Here the insect occurred commonly and in apparently pure populations. Because of the similarity between *R. rigidana* and *R. frustrana,* special attention was given to identification of moths. Many adult specimens originating at various

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places during several moth generations and years, and from several host species, were referred to a specialist for authentic determination. Nothing indicated that any species but *R. rigidana* was involved in the infestations studied.

In Maryland and in Mississippi, where the senior author made occasional observations from 1954 to 1956, *R. rigidana* did not occur in pure populations. In Maryland, the species was accompanied in the same woodlands by *R. busckana* Heinrich (only adult specimens found) as well as by *R. frustrana.* In Mississippi, *R. rigidana* and *R. frustrana* were found developing together on the same trees.

J. F. Gates Clarke of the U. S. National Museum verified the Lepidoptera determinations in this investigation. Moth specimens have been deposited in the U. S. National Museum, the American Museum of Natural History, the Canadian National Collection, the collection of Purdue University, and the collection of the Ohio State University. Specialists of the Insect Identification and Parasite Introduction Laboratories, U. S. Department of Agriculture, identified parasites as follows: Ichneumonidae—L. M. Walkley; Braconidae—C. F. W. Muesebeck; Chalcidoidea (except Eurytomidae)—B. D. Burks; Muscidae—C. W. Sabrosky. J. N. Knull of the Ohio State University identified the Cleridae, and R. E. Bugbee of Allegheny College identified the Eurytomidae. Pines were identified by the senior author and these identifications were occasionally verified by E. L. Little, Jr., of the U. S. Forest Service Herbarium. Nomenclature of pines follows Rehder (1949), except for the slash pines, nomenclature of which follows Little (1953).

TAXONOMY

Rhyacionia rigidana was described by Fernald (Comstock, 1880) from examples bred in New York on pitch pine, *Pinus rigida* Miller. "Pitch pine tip moth" seems an appropriate common name: *Pinus rigida* is frequently infested, and its name served as the source of *"rigidana"*. The most recent taxonomic treatments of the species are those by Heinrich (1923) and Forbes (1923). Heinrich illustrated the male genitalia of most members of the genus *Rhyacionia.*

The shape of the harpe in *R. rigidana* (Figure 1) varies practically none (genitalia of 18 males from six states seen) and this structure can be used to positively differentiate males from those of all but one known relative. The exception is *Rhyacionia* new species, a common pine tip moth which occurs in the Gulf of Mexico region.

R. rigidana can be differentiated from its southern relative by means of forewing coloration, female genitalia, and sometimes geographic distribution. The medial band in the forewing of *R. rigidana* (Figure 2) is less well defined in color and outline than that in *R.* new species. The structure of the ostium in *R. rigidana* (Figure 1) varies only in minor details (genitalia of 10 females from seven states seen), but its pattern differs basically from that in *R.* new species. Geographically, *R. rigidana* does not occur as far south as *R.* new species. The known range of *R.* new species roughly follows the slash pines, *Pinus elliottii* Engelmann var. *elliottii* and *P. elliottii* var. *densa* Little and Dorman. The range of the slash pines is shown in Figure 3.

Discussions of *R. rigidana* in the works by Beal *et al.* (1952) and Wakeley (1954) do not pertain entirely, if at all, to this species: re-examination by the senior author of some specimens from these studies showed the moths to be *R.* new species instead of *R. rigidana.*

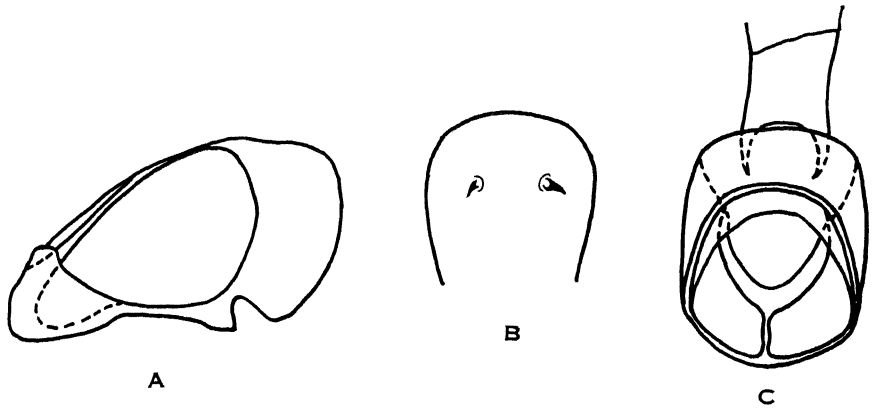

Fig. 1. Genital parts of diagnostic value in **Rhyacionia rigidana.** A. Harpe (male). B. Bursa copulatrix and signum (female). C. Ostium (female). Nomenclature of parts follows Busck (1931) and Busck and Heinrich (1921).

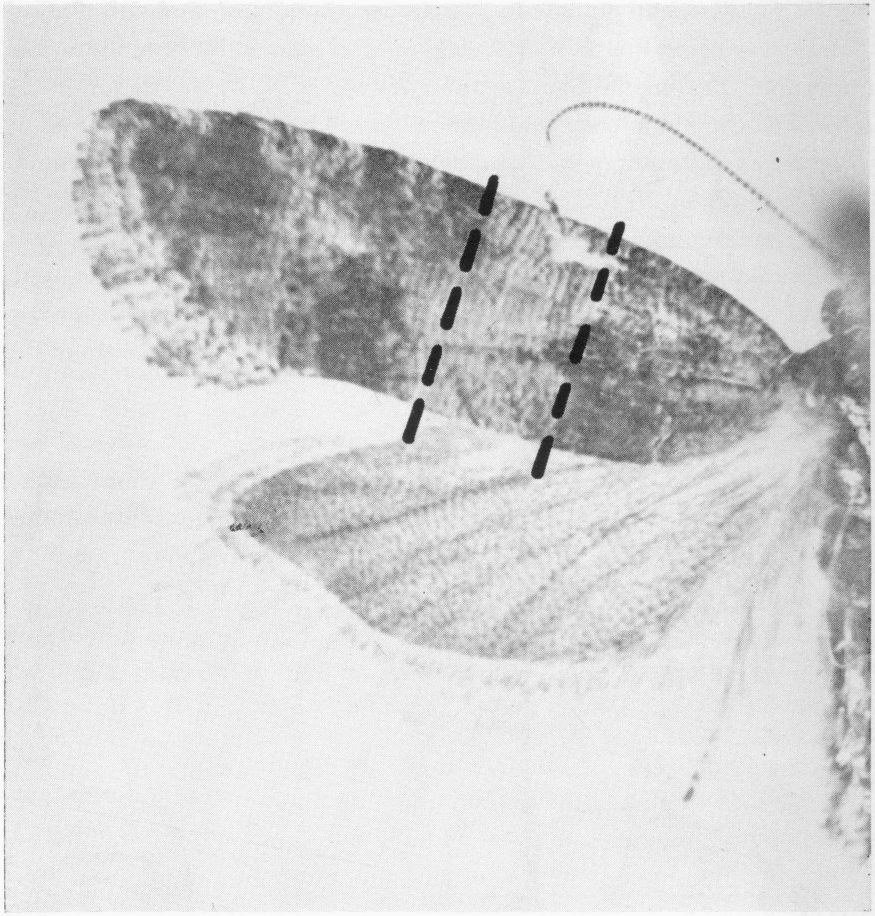

Fig. 2. Rhyacionia rigidana adult from Montgomery Co., Maryland. The broken lines roughly delimit the medial band.

GEOGRAPHIC DISTRIBUTION

Rhyacionia rigidana is undoubtedly a New World species. During a recent trip abroad, the senior author compared the moth with specimens in various European museums. It proved to be distinct from all known Old World pine moths (nearly all of which are listed by Von Kennel, 1908-21).

Figure 3 shows the distribution of the species from available records. Distribution information on *R. frustrana* in and around Ohio is given in Figure 4 for comparison. Distribution information of the following types was used: label data from museum specimens; records originating with the present authors; previously published records; and file records of

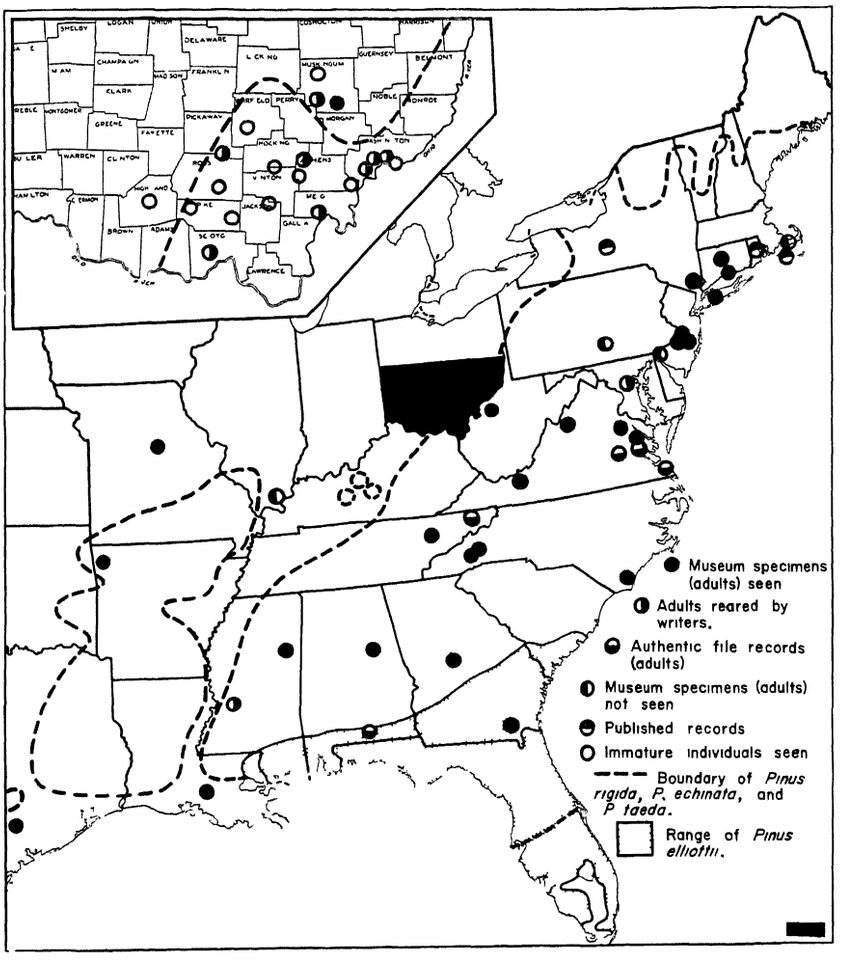

Fig. 3. Distribution of records for **Rhyacionia rigidana** in relation to the natural ranges of host pines. The pine ranges are after Little (1949) and Little and Dorman (1954).

authoritative identifications. Points for which there were more than one type of record were marked on the maps by only one symbol (that for what was considered the most reliable record). The only lepidopterists who had identified specimens constituting file records were Carl Heinrich, reviser of the group (Heinrich, 1923), and H. W. Capps of the U. S. Department of Agriculture Insect Identification and Parasite Introduction Laboratories. Papers not mentioned elsewhere in the text from which distribution data were taken are those by Britton (1934) and Jones and Kimball (1943).

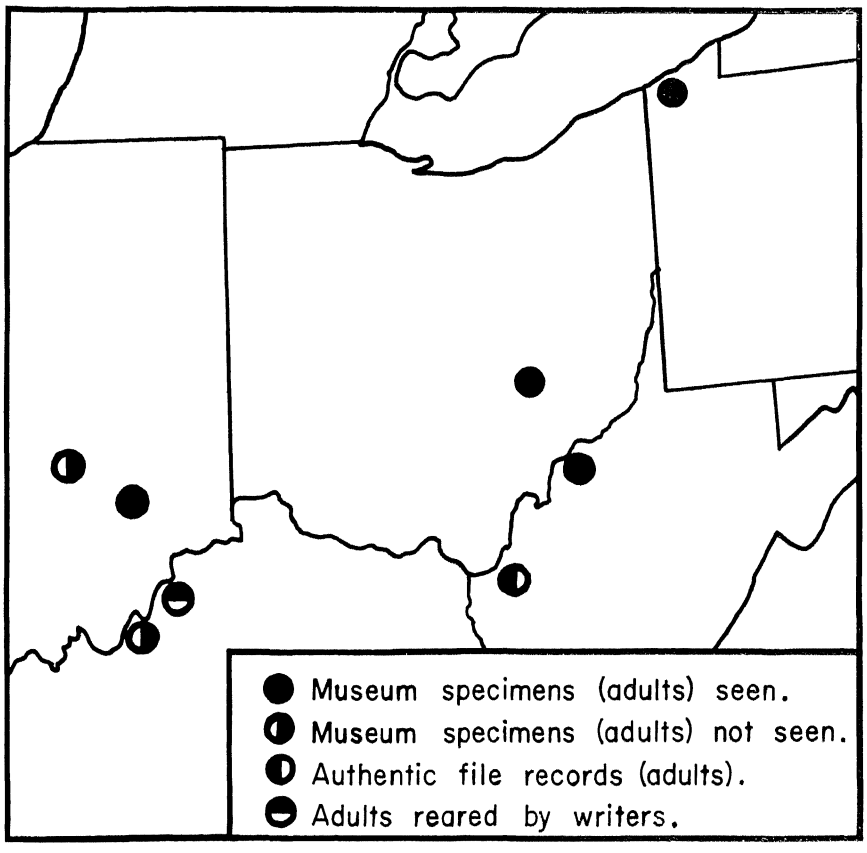

Fig. 4. Distribution of records for **Rhyacionia frustrana** in Ohio and surrounding area.

Institutions and private specialists consulted for distribution records are listed alphabetically below. Those in bold-face type were visited and their collections or files examined by the senior author. Those with an asterisk were able to provide *R. rigidana* records; those with a plus mark, *R. frustrana* records for Ohio and surrounding territory.

American Museum of Natural History*
Arkansas, University of
Braun, A. F.
Brower, A. E.*
Canadian National Collection*
Central States Forest Experiment Station*+
Chicago Natural History Museum
Clemson Agricultural College
Delaware, University of*
Duke University School of Forestry
Illinois Natural History Survey*
Kansas State College
Kansas, University of
Kentucky, University of+
Kimball, C. P.*
Maine Forest Service*
Maryland, University of
Michigan State University
Michigan, University of
Milwaukee Public Museum
Minnesota, Unversity of
Mississippi State College
Museum of Comparative Zoology
New Hampshire Department of Agriculture
New York State Museum
New York, State University of, College of Forestry*
North Carolina Department of Agriculture
North Carolina State College
Northeastern Forest Experiment Station*
Ohio Agricultural Experiment Station*+
Ohio State University
Oklahoma A. and M. College
Pennsylvania Department of Agriculture*
Pennsylvania State University
Philadelphia, Academy of Natural Sciences of*
Purdue University+

Southeastern Forest Experiment Station*
Southern Forest Experiment Station*
Texas A. and M. College
U. S. D. A., Cooperative Economic Insect Survey Section*+
U. S. National Museum*+
Vermont Agricultural Experiment Station
Vermont Department of Agriculture
Vermont Department of Forests and Parks
West Virginia University

The area circumscribed by the points on the distribution map (Figure 3) does not necessarily indicate a permanent distribution of *R. rigidana.* Many points are based only on single-specimen records from isolated time intervals. Where observations on the insect's abundance over longer periods are lacking, the apparent distribution limits should be viewed with two considerations: first, that such limits may fluctuate, and second, that the insect may have been introduced (as on planting stock) to areas where it did not persist. Possibly there are also areas in which the insect has gone undetected.

RHYACIONIA RIGIDANA Versus R. FRUSTRANA in Ohio

In this study, three years' assiduous rearing and identifying tip moth individuals in southern Ohio revealed the presence of only *Rhyacionia rigidana.* In contrast, previous tip moth reports in southern Ohio (Polivka and Houser, 1936; Hall, 1936; Polivka and Alderman, 1937; Polivka, 1938, 1940; Paton *et al.,* 1944) mention only *R. frustrana.* A search was made for information that might help to resolve this disagreement.

A check of the Ohio Agricultural Experiment Station insect collection brought to light 15 *Rhyacionia* specimens reared by Polivka and Houser during their study. These specimens were reidentified, and 14 proved to be *R. rigidana* and only one *R. frustrana.* The present writers made many tip moth collections at places where Polivka and Houser had worked, but only *R. rigidana* was found.

Hall's (1936) report brought out that tip moth infested planting stock had been distributed widely in the Central States in the early 1930's and that infested shortleaf and other pines from surrounding states had been planted in Ohio. No specimens or identification records from Hall's study could be found. However, the planting stock in question could have been infested with both tip moths because both were then probably occurring through much of the Central States region (Figures 3 and 4).

In searching more widely for original evidence concerning the presence of *R. frustrana* in Ohio at any time, the writers consulted 45 institutions and private taxonomic specialists (see previous section for list). Only the Central States Forest Experiment Station could supply any additional *R. frustrana* records for Ohio. It reported (D. E. Donley, personal communication) that extensive rearing of tip moths in Muskingum and Morgan Counties during 1957 produced *R. frustrana* as well as *R. rigidana* moths, but that *R. rigidana* predominated in numbers. The senior author examined specimens of both species from these rearings and verified the identifications.

Both *R. rigidana* and *R. frustrana* are therefore to be found in Ohio, but the available evidence indicates that *R. rigidana* is the commoner tip moth there. *R. frustrana* is inferred to be occurring at lower population levels in Ohio than in many other places. Also, the insect possibly is present only intermittently at various points in Ohio, and possibly is more sparse in terms of distances between infestations there.

HOSTS

The pitch pine tip moth is known to feed only on members of the genus *Pinus*. Ten native pines (Little, 1949, and Harlow and Harrar, 1950) are found within the area of the geographic records for *Rhyacionia rigidana* mapped in Figure 3. Six of these pines have been recorded as hosts, and they are given below. All host records listed as unpublished were obtained from labels accompanying pinned moth specimens. A question mark preceding a scientific name means either that a name had been used which is today a synonym for more than one kind of pine, or that the host had been indicated merely by a common name.

RED PINE, *Pinus resinosa* Aiton. Friend (1934) and others—Connecticut; Schaffner (1950) and others—New York; Univ. of Delaware (unpublished)—Delaware; the authors' records—Ohio and Maryland.

PITCH PINE, *P. rigida* Miller. Comstock (1880) and others—New York; the authors' records—Ohio and Maryland; Heinrich (1923); Schaffner (1950).

SHORTLEAF PINE, *P. echinata* Miller. U. S. Nat. Mus. (unpublished) and others—North Carolina; the authors' records—Ohio and Mississippi.

LOBLOLLY PINE, *P. taeda* Linnaeus. U. S. Nat. Mus. (unpublished)—Virginia; Southern Forest Exper. Sta. (unpublished)—Texas; Southeastern Forest Exper. Sta. (unpublished)—Georgia; the authors' records—Mississippi; Heinrich (1923); Doane *et al.* (1936); Schaffner (1950).

SLASH PINE, ? *P. elliottii* var. *elliottii* Engelmann. Southern Forest Exper. Sta. (unpublished)—Alabama.

VIRGINIA PINE, *P. virginiana* Miller. U. S. Nat. Mus. (unpublished)—West Virginia; Heinrich (1923); Doane *et al.* (1936); Schaffner (1950). In Ohio, injury and developing larvae were occasionally observed on Virginia pine, but no adults were reared from it.

Four pines introduced into the Eastern United States from other areas have also been recorded as hosts:

WESTERN YELLOW PINE, ? *Pinus ponderosa* Douglas. U. S. Nat. Mus. (unpublished)—Arkansas; Illinois Nat. Hist. Survey (unpublished)—Illinois.

AUSTRIAN PINE, ? *P. nigra* Arnold. U. S. Nat. Mus. (unpublished)—New York and West Virginia.

CORSICAN PINE, *P. nigra* var. *poiretiana* (Antoine). U. S. Nat. Mus. (unpublished)—North Carolina; Heinrich (1923); Schaffner (1950).

SCOTCH PINE, *P. silvestris* Linnaeus. Heinrich (1923); Doane *et al.* (1936); Schaffner (1950).

Jack pine, *Pinus banksiana* Lambert, is given by Polivka and Houser (1936) as a host of *Rhyacionia frustrana* in Ohio. This record may have pertained to *R. rigidana* since this species is now known to have been involved in the observations made by Polivka and Houser.

Several points on the *R. rigidana* distribution map (Figure 3) fall outside the natural ranges of native hosts (in Illinois, Louisiana, Missouri, Ohio and Texas). It is not known how persistent most of these infestations were, but the records serve to indicate a tendency for the insect to spread along with its hosts as they are planted in new places. Factors holding back population buildup in nonendemic areas, where *R. rigidana* can be viewed as an introduced insect, conceivably might not operate as well as in endemic areas. It should be recognized that *R. rigidana* could become a more serious pest where its hosts are being extensively planted outside the insect's natural range.

SEASONAL HISTORY

Rhyacionia rigidana normally produces two generations a year in Ohio. The same voltinism was reported by Friend (1934) for Connecticut, and by Heinrich (1923). In Ohio, no intense winter diapause seemed to occur: pupae emerged readily when brought indoors in fall and winter, and a few pupae of the generation about to overwinter produced moths naturally in late summer (partial third brood). Farther south there are probably more than two generations a year.

Egg Stage. Eggs laid in glass jars in the insectary at Wooster, Ohio, were yellow and disc shaped. All proved to be infertile. Eggs were never found in nature, but it seems likely that they are deposited on or near the new growth. The shortest period observed between initial moth emergence and initial observation of young larvae at the same site was 13 days in spring and 23 days in summer.

Larval Stage. Incipient larval activity of the summer generation was observed on May 1, 1952, and May 14, 1953, and of the wintering generation, on August 1, 1952, and July 30, 1953. The approximate length of the larval stage (initial observation of newborn larvae till that of initial pupating) in spring was six weeks, and in summer four weeks.

On shortleaf pine, recently hatched larvae produced two types of feeding signs depending on the age of the attacked shoot. Only dry, powdery frass was found on very young shoots (Figure 5), whereas resinous tents between needle bases were typically present on older shoots (Figure 6). The young larvae bored directly into the younger, softer shoots in which resin canals presumably had not yet developed, and no tents were found on these shoots. On the older, tougher shoots, where the larvae fed first at needle bases, resin canals were present and were punctured. Tents of silk were built on these shoots by the larvae, and the tents served as depositories to which the larvae transported resin, frass, and other debris.

Pupal Stage. Pupation takes place in the larval burrow. Just before transformation, the larva eats away an area of the burrow wall about as big around as itself till the wall is very thin. This area later serves as the pupal exit. The larva also spins a silken mat on the walls of the burrow. The mat protects the pupa from the sticky resin. It also engages the backwardly directed spines of the pupal abdomen, and thus aids pupal movements. Just before the adult issues, the pupa works itself part way out of the bud or shoot by abdominal manipulations. The moth emerges from this characteristic position of the pupa. After emergence, many empty pupal skins remain for a time protruding

through the pupal exit. In cages, some pupae worked themselves completely out of their shoots at emergence. It therefore seems likely that in nature some pupae fall to the ground just before the moth emerges.

Observations made in Ohio, Maryland and Mississippi show that in these places the pupal stage is the wintering form of the species. Similar observations were made by Friend (1934) in Connecticut and by Heinrich (1923). In Ohio, the pupal period of the wintering generation lasted about seven months, and that of the summer generation about six weeks (Table 1).

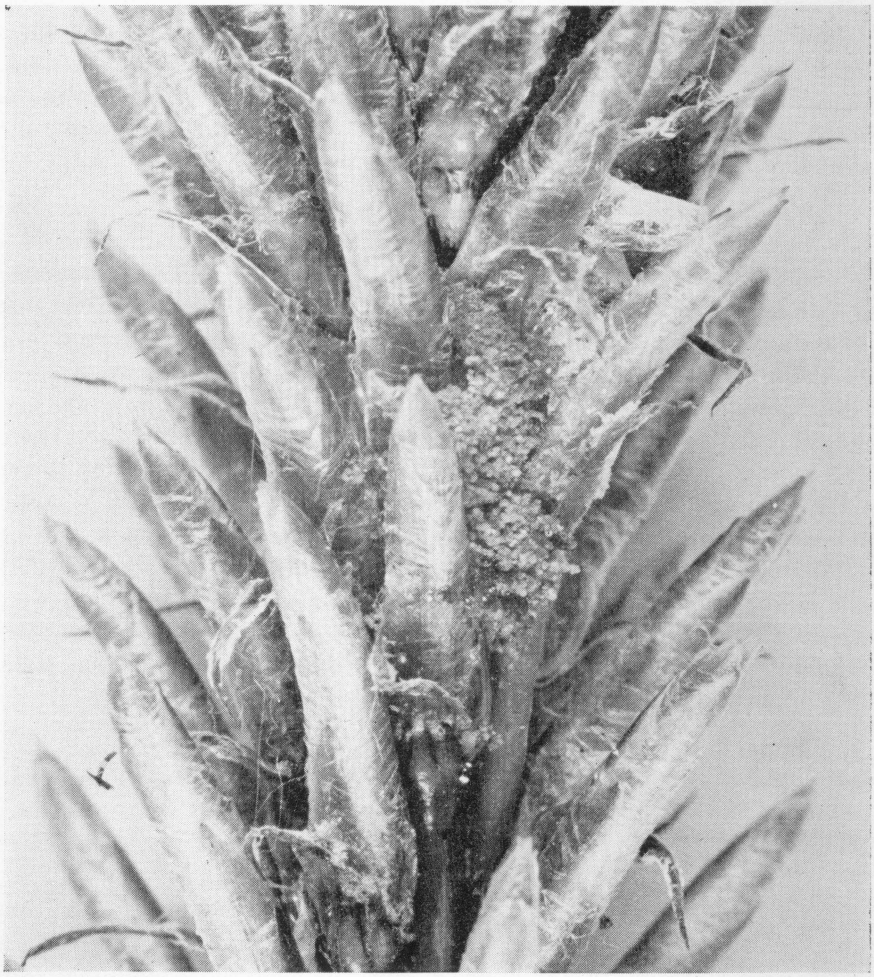

Fig. 5. Portion of a new shoot of **Pinus echinata** showing frass produced by one or more recently hatched larvae. Neither resin exudate nor tent is present.

Emergence and Adult Stage. Emergence records were obtained in the insectary at Wooster and also from periodic samplings in nature (Tables 1 and 2). The dates of first insectary emergence for the wintering generation were April 17, 1952, and April 4, 1953; and for the summer generation, July 4, 1951, July 3, 1952 and June 25, 1953.

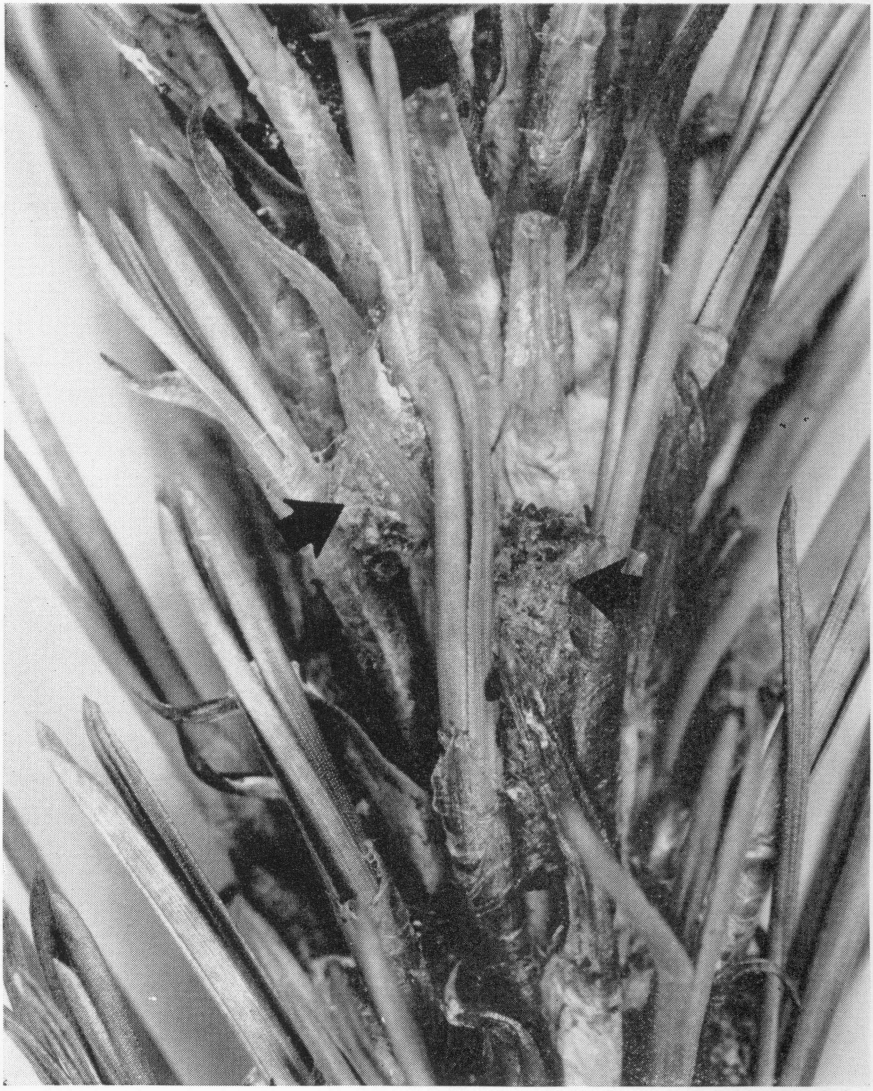

Fig. 6. Portion of a shoot of **Pinus echinata** showing resinous tents (arrows) between needle bases.

Wintering generation moths emerged from five separate tip collections over periods ranging from 15 to 34 days, averaging 22 days. Summer generation moths emerged from three tip collections over periods of 18 to 32 days, averaging 24 days. These tip collections were of such size that each produced between 31 and 121 moths. A mean period of eight

TABLE 1.—Pitch pine tip moth pupation and emergence in the field in Ohio

Date	Number Individuals Observed*	Percentage Pupation	Percentage Emergence
	Wintering Generation		
	1951–52		
September 6-7	90	67	----
April 3	10	100	0
May 1-2	57	100	100
	1952–53		
September 8	31	87	0
April 16-17	61	100	66
April 30	59	100	98
	1953–54		
September 3-4	29	17	0
	Summer Generation		
	1951		
May 25	11	0	----
June 21-28	63	57	0
July 19-20	75	100	88
	1952		
May 1-2	75	0	----
June 26-27	31	77	0
July 11	40	86	28
	1953		
June 18-19	81	45	0
July 10	45	89	53
July 31	100	98	86

*Each figure represents observations made at from 1 to 3, but on the average at 2, study sites.

days, varying from 1 to 14 days, passed from the time infested tips were placed in the insectary till emergence began. Table 2 shows that field and insectary emergence took place at about equal rates.

TABLE 2.—Pitch pine tip moth emergence in the insectary at Wooster, Ohio

Date	Percentage Emergence	Deviation of Insectary Emergence Percentages from Field Emergence Percentages
	Wintering Generation	
	1951–52	
April 3*	0	None
20	30	----
22	70	----
May 2	98	—2
	1952–53	
April 13	30	----
17	36	—30
27	70	----
30	84	—14
	Summer Generation	
	1951	
June 28	0	None
July 12	30	----
18	70	----
20	84	—4
	1952	
June 27	0	None
July 6	30	----
11	58	+30
13	70	----
	1953	
June 19	0	None
July 2	30	----
9	70	----
10	73	+20
31	100	+14

*Boldface indicates dates on which field emergence observations were made (see Table 1).

The sex ratio of adults was about unity. Pairs of adults were placed for mating in jars of 30 cubic inches and in plastic-screen or muslin covered wooden frames of two cubic feet. None of the females laid fertile eggs and this suggested that mating never occurred.

The preoviposition periods for two unmated females were one and two days. The number of eggs (infertile) laid per female by four unmated females in glass jars averaged 27. The two longest lived females (12 and 14 days) laid totals of 20 and 48 eggs. The most eggs laid by one female was 48.

The length of life of 10 females of the wintering generation varied from two to 14 days and averaged eight days. Four males lived from one to seven days, averaging three days. All of these moths were held in small groups in muslin covered jars without food or water.

Rhyacionia rigidana normally wintered as a pupa, but in the Shawnee Forest one individual was found which had wintered as a tiny larva. This observation suggested that a partial third brood of moths had been present the previous summer. Late the following summer, collections of infested shoots from two places in southern Ohio were brought to the Wooster insectary and watched for such emergence. Several moths emerged from one of these collections on September 10 and 11, 1952.

PARASITES AND PREDATORS

Table 3 shows rates of parasitization in tips brought to the insectary. Parasitization in the wintering host generation was probably higher than these figures indicate; the effect of parasites that had emerged in late summer and early fall could not be shown by rearings the following spring. Adults of *Eurytoma pini* Bugbee were seen emerging in the field in September. Also, late summer collections of tips held in the insectary produced in September adults of *E. pini,* as well as *Calliephialtes comstockii* (Cresson) and *Agathis acrobasidis* (Cushman).

The three most frequent parasites of the pitch pine tip moth in Ohio were *Campoplex* sp. (Ichneumonidae), *Eurytoma pini* (Eurytomidae), and *Perilampus fulvicornis* Ashmead (Perilampidae). All three affected both major annual host generations. *P. fulvicornis* probably was hyperparasitic chiefly through one or both of the preceding two species. Other parasites which appeared in the emergence cages of both host generations were: *Agathis annulipes* (Cresson) and *Bracon gemmaecola* (Cushman) (Braconidae); *Calliephialtes comstockii* and *Scambus hispae* (Harris) (Ichneumonidae); *Tetrastichus* sp. (Eulophidae); *Haltichella rhyacioniae* Gahan (Chalcididae); and *Habrocytus thyridopterigis*

TABLE 3.—Pitch pine tip moth parasitization in Ohio as determined from insectary emergence records, 1951-53

Host generation	Total number moths and parasites*	Percentage Campoplex sp.	Percentage Eurytoma pini	Percentage others†	Total percentage parasites
Wintering	278	7	3	7	17‡
Summer	253	11	6	7	24§

* † Small parasites (**Haltichella rhyacioniae, Hyssopus thymus,** and **Habrocytus thyridopterigis**) developed in aggregations of several individuals per host, with those from the same host individual emerging about the same time Such groups were equated to solitary parasites in the computations

‡Varied from 9 to 21 percent in collections from three study localities in two counties.

§Varied from 15 to 48 percent in collections from three study localities in three counties.

Howard (Pteromalidae). Parasites which appeared in emergence cages of one host generation only were: *Hyssopus thymus* Girault (Eulophidae); *Agathis acrobasidis*, *Bracon hebetor* Say, *Cremastus* sp., and *Derostenus* sp. (Braconidae); and *Coenosia* sp. (Muscidae). Information on the biologies of several of the more common parasites is contained in the papers by Miller (1953, 1955).

Clerid larvae occasionally preyed on developing tip moth individuals. In Ohio, these larvae were most commonly met with during September. Adult clerids emerged during the first half of June from caged tips in the insectary. One of these adults was identified as *Isohydnocera tabida* (Leconte). In Mississippi, an adult of *Phyllobaenus* sp. was reared from tips infested with *Rhyacionia rigidana* and *R. frustrana.* Sometimes tips were observed whose appearance suggested that birds had removed the larvae or pupae.

INCIDENCE

Rhyacionia rigidana individuals were found in trees as small as three feet tall, and at the other extreme, in the crown of a felled pitch pine tree whose stump measured 15 inches in diameter. In young trees, a tendency was noted for the infestation to concentrate on the upper branches.

The following figures on density of the insect are from two infestations which seemed fairly typical of the densities observed in 18 of the 19 infestations seen in southern Ohio. The two plantations contained red and pitch pine trees about five feet tall. They had 20 and 50 percent of the sample trees infested, with means of 0.5 and 1.5 infested tips per sample tree and 2.5 and 3.1 infested tips per infested sample tree (40

trees sampled in each planting). These counts were made after larvae had caused conspicuous injury to the tips. Similar infestation figures were reported earlier for Ohio by Polivka and Houser (1936), and it has been shown that these authors were dealing in part with *R. rigidana.*

The most severe infestation encountered in Ohio was in a 2½-acre plantation of shortleaf pine where trees averaged seven feet tall. Early in the spring of 1951, 100 percent of the trees and 80 percent of the shoots were found injured. More than 300 tips containing wintered pupae were collected at this plantation on two different dates in early spring and placed in the insectary for moth emergence. A few parasites (*Eurytoma pini* and others) emerged from these tips, but no moths appeared. Subsequent field and laboratory dissections of tips revealed only dead pupae. A catastrophic pupal kill had taken place, but its cause was not determined. Although the identity of the tip moth was not established at this time, a *Rhyacionia rigidana* population was definitely present later. It remained at a low level during the remainder of this study.

The pitch pine tip moth commonly infests red, pitch and shortleaf pines in Ohio. In one planting where degree of infestation in pitch and red pine could be directly compared, red pine was found exhibiting the greater infestation. This planting consisted of several acres of alternating rows of pitch and red pine trees. Trees of both species averaged about five feet tall. Two adjacent rows were selected near the center of the planting and 20 consecutive trees in each row were examined. The percentage of trees infested proved to be 35 for pitch pine and 65 for red. The number of tips injured per infested tree averaged two for pitch (varying from one to three) and four for red (varying from two to six).

Toward the end of the larval stage, the number of individuals per shoot was tallied. Red and shortleaf pines had greater numbers of maturing individuals per shoot than pitch pine. Red pine had up to 14 individuals per shoot, averaging 3.1 (144 shoots); shortleaf pine, up to eight per shoot, averaging 2.7 (76 shoots); and pitch pine, up to five per shoot, averaging 1.7 (57 shoots).

INJURY

The injury caused by *Rhyacionia rigidana* can be classified as shoot injury or bud injury depending on the extent of larval feeding. Shoot feeding results in the killing back of the shoot for several inches, often to the previous node. When only the buds on a shoot are fed upon, the resulting damage to the tree is not likely to be as severe as that which occurs when whole shoots are attacked.

If leaders are infested, deformation in the stems of the trees may result. Even when the insect is at its usual low density, a large proportion of the infested tips are leaders. In the plantations described earlier as supporting populations of typical densities, 11 percent of all sample trees and 32 percent of infested sample trees had infested leaders.

The first conspicuous effects of infestation by the summer generation on shortleaf pine trees appeared about two weeks after the larvae started hatching. At this time, many infested shoots could be spotted by their retarded growth and reddish brown discoloration.

SUMMARY AND CONCLUSIONS

1. The pitch pine tip moth, *Rhyacionia rigidana* (Fernald), is similar in many ways to the better known Nantucket pine moth, *R. frustrana* (Comstock). *R. rigidana* may occur on the same trees with *R. frustrana.* The ecology of *R. rigidana* was investigated in Ohio from 1951 through 1953.

2. *R. rigidana* has been found from Texas and Georgia north to Missouri, New York and Massachusetts.

3. In a previous tip moth investigation in Ohio, *R. rigidana* specimens were mistakenly identified as *R. frustrana. R. frustrana* occurs in Ohio, but *R. rigidana* appears to be the more abundant tip moth there.

4. Six native and four introduced pines have been recorded as hosts, and these are in the hard pine group.

5. In the northern part of its range, *R. rigidana* has two generations a year, with the winter being spent in the pupal stage on the trees. In Ohio, the adults are present in April and in July, and sometimes there is a small partial third emergence of moths in late summer.

6. Many species of parasites and predators attack the pitch pine tip moth in Ohio. About 25 percent of the pupae and mature larvae were parasitized.

7. *R. rigidana* occurred in Ohio on trees of nearly all sizes. Usual population densities were about one aggregation of developing individuals (one infested tip) per tree on trees approaching sapling size. There seemed to be slight differences in the numbers and sizes of aggregations per tree on different pine species.

8. The larvae kill buds and shoots. This may deform stems and retard height growth of infested trees.

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